high, suggesting that junction potentials are superior to a continuous surface depletion layer as a transduction mechanism for chemisorption. Using a catalyst deposited upon the surface in the form of nanoparticles yields dramatic gains in sensitivity for both nanostructured, one-dimensional forms.

For the nanowire materials, the response magnitude and response rate uniformly increase with increasing operating temperature. Such changes are interpreted in terms of accelerated surface diffusional processes, yielding greater access to chemisorbed oxygen species and faster dissociative chemisorption, respectively. Regardless of operating temperature, sensitivity of the nanofibers is a factor of 10 to 100 greater than that of nanowires with the same catalyst for the same test condition. In summary, nanostructure appears critical to governing the reactivity, as measured by electrical resistance of these SnO_2 nanomaterials towards reducing gases. With regard to the sensitivity of the different nascent nanostructures, the electrospun nanofibers appear preferable.

This work was done by Gary W. Hunter, Laura Evans, and Jennifer C. Xu of Glenn Research Center; Randy L. Vander Wal of Penn State University; and Gordon M. Berger and Michael J. Kulis of the National Center for Space Exploration Research. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18492-1.

Lightweight, Ultra-High-Temperature, CMC-Lined Carbon/Carbon Structures

This refractory composite material is applicable to defense vehicles, combustion chambers, rocket nozzles, hot gas generators, and valves using both liquid and solid propellants.

John H. Glenn Research Center, Cleveland, Ohio

Carbon/carbon (C/C) is an established engineering material used extensively in aerospace. The beneficial properties of C/C include high strength, low density, and toughness. Its shortcoming is its limited usability at temperatures higher than the oxidation temperature of carbon — approximately 400 °C. Ceramic matrix composites (CMCs) are used instead, but carry a weight penalty. Combining a thin laminate of CMC to a bulk structure of C/C retains all of the benefits of C/C with the high temperature oxidizing environment usability of CMCs.

Ultramet demonstrated the feasibility of combining the light weight of C/C composites with the oxidation resistance of zirconium carbide (ZrC) and zirconium-silicon carbide (Zr-Si-C) CMCs in a unique system composed of a C/C primary structure with an integral CMC liner with temperature capability up to 4,200 °F (≈2,315 °C). The system effectively bridged the gap in weight and performance between coated C/C and bulk CMCs. Fabrication was demonstrated through an innovative variant of Ultramet's rapid, pressureless melt infiltration processing technology. The fully developed material system has strength that is comparable with that of C/C, lower density than Cf/SiC, and ultra-high-temperature oxidation stability. Application of the reinforced ceramic casing to a predominantly C/C structure creates a highly innovative material with the potential to achieve the long-sought goal of long-term, cyclic high-temperature use of C/C in an oxidizing environment. The C/C substructure provided most of the mechanical integrity, and the CMC strengths achieved appeared to be sufficient to allow the CMC to perform its primary function of protecting the C/C.

Nozzle extension components were fabricated and successfully hot-fire tested. Test results showed good thermochemical and thermomechanical stability of the CMC, as well as excellent interfacial bonding between the CMC liner and the underlying C/C structure. In particular, hafnium-containing CMCs on C/C were shown to perform well at temperatures exceeding 3,500 °F (≈1,925 °C).

The melt-infiltrated CMC-lined C/C composites offered a lower density than Cf/SiC. The melt-infiltrated composites offer greater use temperature than Cf/SiC because of the more refractory ceramic matrices and the C/C substructure provides greater high-temperature strength.

The progress made in this work will allow multiple high-temperature components used in oxidizing environments to take advantage of the low density and high strength of C/C combined with the high-temperature oxidation resistance of melt-infiltrated CMCs.

This work was done by Matthew J. Wright, Gautham Ramachandran, and Brian E. Williams of Ultramet for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18618-1.